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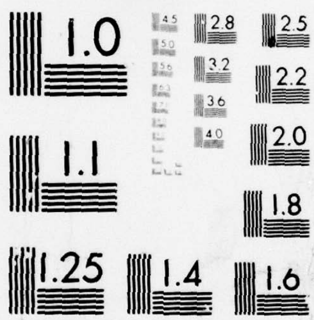


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OCTOBER 1979 LEVEL II (12) SC TP 5-79

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# AN ALGORITHM FOR DETERMINING DELAYS IMPOSED ON GROUND FORCES DUE TO INTERDICTION AIR STRIKES REVISITED

## Technical Paper 5-79





# UNITED STATES ARMY COMBINED ARMS CENTER



COMBINED ARMS
COMBAT DEVELOPMENTS ACTIVITY
COMBAT OPERATIONS ANALYSIS DIRECTORATE

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(6)

# An Algorithm for Determining Delays Imposed on Ground Forces Due to Interdiction Air Strikes Revisited

ACN 36819

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## ABSTRACT

This technical paper presents modifications to the methodology concerning delay imposed on ground forces due to interdiction air strikes as presented in CACDA TP 3-79. That paper presented the rationale underlying the development of a new delay methodology for TALON. The methodology involves four types of mutually exclusive, exhaustive delay events that were imposed upon regiments due to air strikes. This paper briefly reviews the computations for three of those delays and presents a new technique for computing delay caused by crater-producing munitions. This paper also details the resultant delay from the interaction of consecutive but separate flights of two to four aircraft. The total regimental delay is the sum of the four types of delay in the case of an air strike against an undelayed regiment. However, if the regiment is currently in a delay status from a previous air strike, then the resultant total delay for the regiment depends on the type of delay being imposed at the time of the subsequent strike. Example delays are given for attacks of one, two, and four aircraft. The methodology is equally applicable for Blue delay due to Red air strikes as well as Red delay due to Blue air strikes.

# TABLE OF CONTENTS

## Technical Paper TP 5-79

1. INTRODUCTION. This paper is a second iteration of a methodology that quantifies delay of second echelon forces based on air attacks (interdiction) against those forces. The first iteration is contained in CACDA Technical Paper TP 3-79 (reference 3), which states that a joint project was undertaken by the USAF Tactical Fighter Weapons Center (TFWC) and the USA Combined Arms Combat Developments Activity (CACDA) in November of 1978 to determine what tactical air resources would be required to delay advancing second echelon Red forces and what opportunities would present themselves to the Blue commander if significant delays could be achieved. The primary model used to conduct this study was the Tactical Air/Land Operations (TALON) model at TFWC. Since the delay methodology being used in TALON at that time was not valid for a deep interdiction study, a new delay methodology was required. Background for this methodology remains the same as in TP 3-79, pages 1-2. The methodology has been extended in two areas:

- Interaction of consecutive but separate flights of two to four aircraft, where each aircraft in a flight may make one or more hot passes over a target.

- Modification of impaired movement delay due to crater employment.

2. OVERVIEW. The general approach to delay of second echelon forces by one flight of two to four aircraft is the same as in TP 3-79. In that document there are four mutually exclusive, exhaustive delay events, with associated delay times defined as follows:

- Heads Down Time (HD) -- the initial reaction of the Red forces to Blue air attack.

- Damage Assessment Time (DA) - the time required for a commander to receive reports from his subordinates, assess the situation, and then report to his higher headquarters.

- Damage Control Time (DC) -- the time required to treat personnel casualties (first aid) and recover undamaged and/or slightly damaged vehicles.

- Impaired Movement Time (IM) -- the time required to bypass craters and remove burning vehicles and other obstacles from the road.

This methodology addresses the expected time delays assessed against a single regiment of 12 companies. It does not assess casualties to the companies of the regiment. In this paper the term "hot pass" or "pass" is used to denote one aircraft flying over and attacking a company in the regiment once. A "flight" is a set of aircraft making hot passes at the same time. Typically, a flight consists of two aircraft making one or more hot passes at 5 or more minutes separation from other flights. A "strike" denotes a group of aircraft sent to attack a regiment. The

assumptions for this approach are the same as in TP 3-79; in particular, complete intelligence, no adverse weather, and single companies attacked (usually) by two, three, or four aircraft. Appendix B is a program in BASIC that computes regimental delay based on the number of hot passes in each flight, starting times of the flights (input in ascending order), whether or not crater munitions are employed, and the effectiveness of the munitions employed. These inputs could be entered directly, provided by data, or computed internally in TALON or other war games from gamer orders, for each critical incident. This methodology does not address the delay of forces when several regiments are interdicted.

3. DELAY CALCULATIONS FOR ONE FLIGHT. This paragraph outlines the calculations for the four delays. The first three are the same as in TP 3-79; the impaired movement delay calculations have been changed. The basic data come from the "Minutes of an Exploratory Meeting on Interdiction Study AC 243," NATO Panel VII, 1-3 February 1978 (reference 1). Further details on the method, how data were obtained, and the derivation of the formulas (especially the first three) are in TP 3-79. That paper also relates the number of companies attacked as a function of the number of hot passes in a flight.

a. <u>Heads Down Time (HD)</u>. If the regimental column was moving, it was assumed that the regimental delay would be the same as for a single company (as was being done in TALON at that time). For a stationary regiment dispersed in an assembly area, it was assumed that the delay would be degraded by the fraction of companies attacked to total companies, thus:

- If the regiment is moving in columns, regimental HD delay = (number of hot passes)* (1 minute)

- If the regiment is not moving, regimental HD delay = (number of hot passes)* (fraction of companies attacked)* (1 minute)

b. <u>Damage Assessment Time (DA)</u>. The following assumptions regarding the damage assessment event were made:

- Damage will <u>always</u> occur because of the highly effective new interdiction munitions being employed by Blue aircraft (such as Wide Area Antiarmor Munitions (WAAM)).

- Only armor and motorized rifle units are of interest. If they can be delayed, the "other" units are of no concern.

- Attacks against armor and motorized rifle units are equally likely.

These assumptions and the NATO study were used in TP 3-79 to compute the expected delay required for a company to assess damage. Since this damage would usually occur in some small number of companies, the regimental delay was "deweighted" thus:

- Regimental DA delay = (expected delay for company DA)* (fraction of companies attacked)

c. Damage Control Time (DC). The following assumptions regarding the damage control event were made:

- First aid and vehicle recovery can be accomplished in parallel since medics will normally be involved in first aid, and mechanics and crew will be involved in vehicle recovery.

- Recovery of both undamaged trucks and undamaged fighting vehicles will be required.

- Three cases of first aid (five or fewer casualties, six to ten casualties, and more than ten casualties) are equally likely.

These assumptions and the NATO study were used in TP 3-79 to compute the expected time for a company to control damage. The maximum of first aid delay and vehicle recovery delay is used in the NATO computed company delay below, since first aid and vehicle recovery were assumed to be done in parallel. Rand Report R-1194-PR, May 74 (reference 2), currently applied in TALON, was also considered. It was decided to use the maximum of the two delays (NATO and Rand). The Rand formula below uses the term "regimental strength" from the TALON model, which stands for the combat mass of the regiment expressed in terms of the value of a representative combat system. Thus, the following computations are performed for DC delay:

- $$\text{fraction of company destroyed} = \left[ \frac{\dfrac{(\text{effectiveness per A/C})*(\text{nr. of passes})}{\text{number of companies attacked}}}{\dfrac{\text{regimental strength}}{\text{number of companies}}} \right]$$

- $$\text{Rand Study company delay} = 720 \left[ \frac{\text{fraction of company destroyed}}{1- \text{fraction of company destroyed}} \right]$$

- NATO company delay = max (first aid delay, recovery delay)

- Company DC delay = max (NATO company delay, Rand study company delay)

- Regimental DC delay = (company DC delay) * (fraction of companies attacked)

d. Impaired Movement Time (IM). The following assumptions regarding the impaired movement event were made:

- The removal of burning vehicles can be accomplished in parallel in all companies attacked.

- Bypassing of bomb craters will be required only when aircraft are carrying crater-producing munitions.

- Craters are bypassed in parallel (see appendix A for definition of parallel).

- Only the front four companies are attacked with crater munitions, and each company is equally likely to be selected for attack (see appendix A).

- No companies are left behind (see appendix A).

- Effectiveness is the probability of getting crater-producing munitions on the road (see appendix A).

This delay is appropriate only for a moving regiment in column. Appendix A develops regimental delay caused by crater producing munitions as a function of the number of companies attacked. These delays are:

| Number of companies attacked | Regimental delay |
|---|---|
| 1 | 42 |
| 2 | 45.33 |
| 3 | 47 |
| 4 | 48 |

The delay due to removing the burning vehicles was computed from the NATO Study in TP 3-79. Thus, the following computations are performed for IM delay for a single flight:

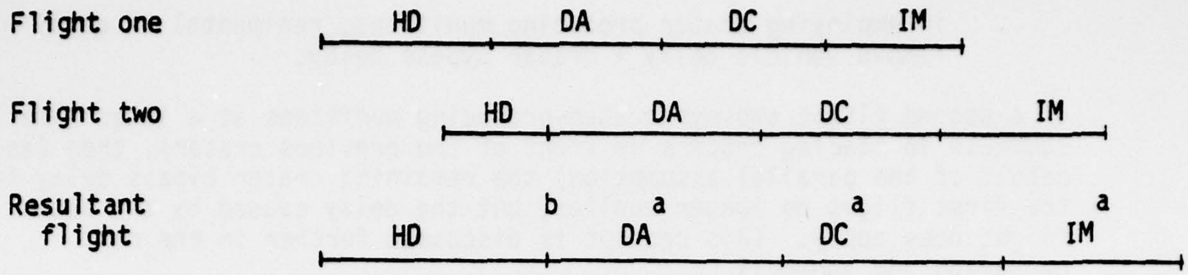
- remove vehicle delay = (expected company time to remove)* $\left\{1-(1-\text{effectiveness})^{(\text{number of passes})}\right\}$
- crater bypass delay = (expected delay determined from appendix A)* $\left\{1-(1-\text{effectiveness})^{(\text{number of passes})}\right\}$
- if not employing crater producing munitions, regimental IM delay = remove vehicle delay

- if employing crater-producing munitions, regimental IM delay = remove vehicle delay + crater bypass delay.

If a second flight employs crater-producing munitions at a later time and succeeds in placing craters in front of the previous craters, then (as a result of the parallel assumption) the remaining crater bypass delay from the first flight no longer applies, but the delay caused by the second flight does apply. This concept is discussed further in the next paragraph and appendix C.

4. INTERACTIONS OF MULTIPLE FLIGHTS. This paragraph details the resultant delay when one flight of aircraft starts before the effects of an earlier flight end; it also defines a resultant flight for use in computing the combined effects of following flights. Since a flight results in four mutually exclusive, consecutive, exhaustive events, we consider five separate cases: the second flight occurring during the heads down event, damage assessment event, damage control event, impaired movement event, or after the effects of the first flight are over. This methodology is predicated upon the separate flights being considered in ascending order of starting time. The approach is an inductive one. The first step in the induction is given in each case below. For the general inductive step, flight one should be replaced by the last resultant flight; flight two replaced by the next flight in sequence; and resultant flight by the new resultant flight. The process continues through all flights.

a. Case 1. Second flight starts during the heads down event. Since the second flight starts before the forces begin damage assessment, we assume heads continue to stay down for the second flight; possibly some self defense starts, but still no damage assessment, control, or substantial movement occurs. Thus, the resultant flight has a heads down time from the start of the first flight until both heads down periods end. Damage assessment, damage control, and impaired movement delays are computed as if the two flights were one (i.e., computed using the total number of hot passes from both flights in the formulas of paragraph 3). The resultant delay is determined based upon these delays from the total number of hot passes and heads down time. See figure 1.

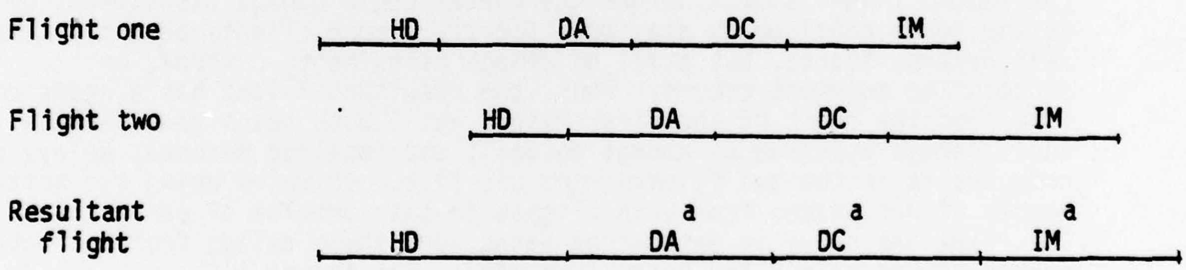



Note: a. DA, DC, IM on resultant flight are computed by considering total aircraft of both flights.

b. This point is the maximum time of heads down from flights one and two.

Figure 1. Case 1, Second flight starts during the heads down event.

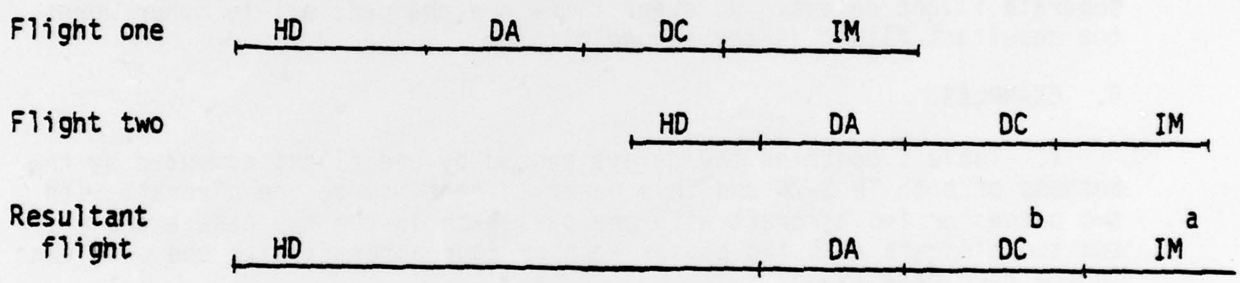
b. Case 2. Second flight starts during the damage assessment event. This methodology assumes that information obtained before the second flight starts is of no value because of confusion, new damage, etc. Thus the resultant flight has a heads down time from the start of the first flight until the end of the heads down period of the second flight. Damage assessment, damage control, and impaired movement delays are then computed as in case 1. See figure 2.




Note: a. DA, DC, IM on resultant flight are computed by considering total aircraft of both flights.

Figure 2. Case 2, Second flight starts during the damage assessment event

c. Case 3. Second flight starts during the damage control event. The methodology assumes that the interrupted damage control event from the first flight may be continued during damage assessment for the second flight. Damage assessment and control for both flights are assumed to be completed before movement resumes; hence, delay due to the impaired movement is computed by considering the total hot passes of both flights as in case 1. The resultant flight is defined to have a heads down period from the start of the first flight to the end of heads down from the second flight. Thus, the resultant heads down event is really a pseudo heads down event. But, since the flight following the second of the two flights which combined to make the resultant flight does start later, its starting time will occur during the actual heads down event or a later event of the second flight. Hence, this process may be continued. The damage assessment event continues until the end of damage assessment from the second flight. Damage control ends at the end of the second flight damage control unless the damage control event of the first flight cannot be completed during the damage assessment event of the second flight. In this case the remaining damage control of the first flight is added to the damage control of the second flight. See figure 3.



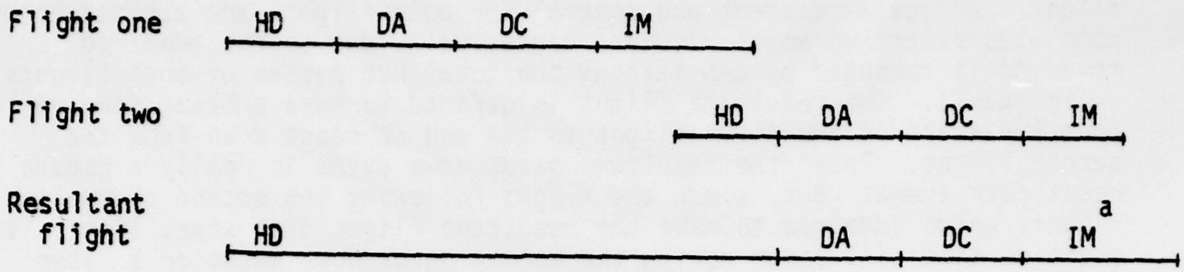

Note: a. IM for resultant flight is computed by considering total aircraft of both flights.

b. DC of flight two plus DC of flight one not completed during DA of flight two.

Figure 3. Case 3, Second flight starts during the damage control event

d. Case 4. Second flight starts during the impaired movement event. In this case the delays due to the first flight are all completed except for a portion of the impaired movement event. This case assumes that actions to correct the interrupted impaired movement event from the first flight may be continued during damage assessment of the second flight. The resultant flight is then one with heads down starting at the start of the first flight and ending at the end of heads down for second flight, damage assessment for second flight, damage control for second flight, and

impaired movement ending at end of impaired movement of second flight plus remaining vehicle removal time from the first flight (not finished during damage assessment of the second flight). See figure 4.




Note: a. IM of flight two plus vehicle removal in IM of flight one not completed during DA of flight two.

Figure 4. Case 4, Second flight starts during the impaired movement event

e. Case 5. Second flight starts after all effects of the previous flight are completed. In this case the total delay is the sum of the two separate flight delays. No event times are changed; or, in other words, the resultant flight is the second flight.

5. EXAMPLES.

a. Table 1 contains the delays caused by one flight computed by the methods of both TP 3-79 and this paper. There may be one aircraft with two passes or two aircraft with one pass each in the two pass examples, and two aircraft with two passes each or four aircraft with one pass each in the four pass examples.

Table 1. Delays Caused by One Flight

Regimental Strength = 265

| | | | | | | |
|---|---|---|---|---|---|---|
| Number of passes | 1 | | 2 | | 2 | |
| Moving ? | Yes | | Yes | | Yes | |
| Craters ? | Yes | | Yes | | No | |
| Effectiveness | .33 | | .33 | | .5 | |
| Delay Time (minutes) | TP 3-79 | This paper | TP 3-79 | This paper | TP 3-79 | This paper |
| HD | 1 | 1 | 2 | 2 | 2 | 2 |
| DA | 2.25 | 2.25 | 4.5 | 4.5 | 4.5 | 4.5 |
| DC | .91 | .91 | 1.82 | 1.82 | 2.78 | 2.78 |
| IM | 9 | 18.48 | 11 | 32.70 | 7 | 10.50 |
| Total | 13.16 | 22.64 | 19.32 | 41.02 | 16.28 | 19.78 |

Table 1. (cont)

| Number of passes | 2 | | 4 | | 4 | | 4 | |
|---|---|---|---|---|---|---|---|---|
| Moving ? | No | | Yes | | Yes | | No | |
| Craters ? | No | | Yes | | No | | No | |
| Effectiveness | .5 | | .33 | | .5 | | .5 | |
| Delay time (minutes) | TP 3-79 | This paper | TP3-79 | This paper | TP3-79 | This paper | TP3-79 | This paper |
| HD | .33 | .33 | 4 | 4 | 4 | 4 | 1.33 | 1.33 |
| DA | 4.5 | 4.5 | 9 | 9 | 9 | 9 | 9 | 9 |
| DC | 2.78 | 2.78 | 3.64 | 3.64 | 5.56 | 5.56 | 5.56 | 5.56 |
| IM | 0 | 0 | 15 | 49.51 | 7 | 13.13 | 0 | 0 |
| Total | 7.61 | 7.61 | 31.64 | 66.15 | 25.56 | 31.68 | 15.89 | 15.89 |

b. Table 2 contains the delays caused by five flights occurring at 5 minute intervals computed by both methods. Again, four passes may mean four aircraft, one pass each; or two aircraft, two passes each, etc.

Table 2. Delays Caused by Five Flights

Regimental Strength = 265
Regiment Moving

| Situation | TP 3-79 Total Delay (minutes) | This paper Total Delay (minutes) |
|---|---|---|
| Five flights: four passes each flight, no crater munitions, effectiveness .5 | 51.68 | 62.65 |
| Five flights: two passes each flight, craters on first and fourth flights, crater effectiveness .33, non-crater effectiveness .5 | 56.02 | 73.90 |

6. DISCUSSION.

a. The modifications recommended for impaired movement are built on assumptions that are intended to reflect actual operations more closely than the previous approach. This delay is an expected delay that depends upon the effectiveness of the munition. This new approach also reflects the need for applying crater-producing munitions near the front of the regimental column. From the previous paragraph, the expected impaired movement delay caused by two passes using cratering munitions with an effectiveness of .33 against a regiment was 11 minutes by the former approach, but 32.7 minutes by the new approach. (Actually, the 11 minutes is independent of effectiveness, whereas the 32.7 would vary with effectiveness.) From the NATO study, it was derived that a company would take 14 minutes to clear the road of damaged vehicles and an extra 4 minutes to bypass any crater the company came upon. If craters can be placed at the front of a column, then each company would take 4 minutes to bypass the crater, so 32.7 minutes seems more reasonable than 11 minutes.

b. The modifications suggested here for the interaction of multiple flights are built upon assumptions concerning four events that result from an attack on a regimental column. These assumptions attempt to reflect the interactions of the multiple passes that were not reflected in the previous version. The interaction rules should be considered open to modification upon further study. The previous approach, which considered the total delay due to overlapping flight to be the time from the start of the first flight to the end of the last flight, ignores the effects of an early flight once a subsequent flight starts, and thus almost certainly underestimates the actual delay. For example, in the TP 3-79 approach a flight of four passes not employing crater munitions would delay a moving regimental column 31.68 minutes. (This delay was obtained using impaired movements as suggested above.) There are two methods for computing the delay caused by five flights of four hot passes each from this delay. The approach used in TP 3-79 would yield a total delay of 51.68 minutes; i.e., the total time from the start of the first flight until the end of the fifth flight without any interaction of the flights. It should be noted that (in this case) the additional delay caused by flights subsequent to the first is only 20 minutes, due totally to the interval between flights. The suggested approach, as implemented by the program at appendix B, computed a delay for the column of 62.65 minutes.

c. Two factors must be considered in the application of this methodology:

(1) Delay in this context means arrival at some point later than the arrival if no delay had been imposed; delay is not the time of a complete stoppage.

(2) The second factor is related to the continual application of delays by this methodology. The basic data in reference 1 were obtained by

questioning military officers. The questions concerned the effects of small formations of aircraft attacking company-sized units; the discussion emphasized initial reactions and the expectation of follow-up raids. However, little was presented on the effects of repeated attacks and the effects of attacks on a column while in a delay status that would lead one to expect the response of the column to further attacks, after many attacks, would be different from the original response. The column may also advance during a long period of continual air strikes and possibly join the forces at the FEBA, so the situation being modeled may change. Therefore, caution must be used in modeling continual air strikes of long duration by this methodology. More specifically, this methodology was designed with the Blue air strike tactic of several small flights at 5 to 10 minute intervals in mind. For this tactic the methodology yields reasonable delay. 'Playing the model' by employing single aircraft flights every 20 minutes to otain indefinite delays is not considered reasonable.

d. It should be noted that the modeling technique employed here is deterministic because it uses only expected values. This approach was considered appropriate since the intended application of the methodology was the TALON model. However, reference 1 contains the probabilities of different responses of a unit to air strikes, as well as some ranges of delay times for different responses. Thus, a stochastic simulation could probably be constructed if a particular application seemed to warrant such an approach.

7. CONCLUSION. The above modifications to the delay methodology of TP 3-79 should be implemented for all future applications of the original delay methodology.

## REFERENCES

1. Minutes of an Exploratory Meeting on Interdiction Study AC243, NATO Panel VII, 1-3 February 1978.

2. Harris, Kathleen and Louis Wegner, Tactical Air Power in NATO Contingencies - A Joint Air Battle/Ground Battle Model (TALLY/TOTEM), Rand Report R-1194-PR, May 1974.

3. Garvey, Richard E., Jr., An Algorithm for Determining Delays Imposed on Ground Forces Due to Interdiction Air Strikes, CACDA Technical Paper TP 3-79, September 79. (NATO RESTRICTED)

## APPENDIX A

### Delay Caused by Craters

The approach used to determine the delay of a regimental column of companies subjected to attack by crater-producing munitions will be termed a "parallel" approach. If several companies in the column have craters to bypass, it is assumed the companies pass the craters in parallel (simultaneously). Thus, the delay caused by craters is really caused by the forwardmost crater and represents the time that the regiment must wait until the last company passes this forward crater in order to resume normal progress. This approach assumes that nothing is done to the cratered area to ease the passing by later companies. According to doctrine, aircraft attempt to attack the front of a column in order to maximize delay. Since detection and/or terrain problems make it difficult to guarantee that the lead company is attacked, we assume that it is equally likely that one of the first four companies is attacked with crater-producing munitions, never any of the remaining eight. If the companies are numbered from front to rear by 1, 2, ---, 12 with i denoting the position in general, and we assume that the expected delay for each company to pass a cratered area is 4 minutes as computed in reference 3, then the delay caused by attacking the ith company is:

$$\begin{aligned} V_i &= (13-i)*(\text{expected delay per company}) \\ &= (13-i)4 \end{aligned} \tag{1}$$

The 13 may be replaced by 12 if one assumes that the last company is left with instructions to catch up later. To continue this approach it is necessary to determine the probability of picking a forward company on a series of crater-producing runs. More carefully stated, an expression for the probability of the kth company being the forwardmost company attacked, given that s of the first four companies are attacked, is required. This probability is denoted by $P\{K=k \mid S=s\}$, and the probability that all

companies attacked are the kth one or one farther back is denoted by $P\{K \geq k \mid S=s\}$.

Then: $$P\{K=k \mid S=s\} = P\{K \geq k \mid S=s\} - P\{K \geq k+1 \mid S=s\} \tag{2}$$

for k = 1, 2, ..., 4-s, s=1, 2 or 3. Note: if k = 5-s, then:

$$P\{5-s \mid s\} = 1 - \sum_{k=1}^{4-s} P\{k \mid s\};$$

also if s = 4, then k = 1, and $P\{1 \mid 4\} = 1$. Since we assume the companies are attacked independently:

$$P\{K \geq k \mid S=s\} = \frac{4-k+1}{4} \cdot \frac{4-k+1-1}{4-1} \cdot \ldots \cdot \frac{4-k+1-(s-1)}{4-(s-1)} \tag{3}$$

$$= \frac{(4-s)!}{4!} \frac{(4-k+1)!}{(4-k+1-s)!}$$

Using expression (3) in (2) we have:

$$P\{K=k \mid S=s\} = \begin{cases} \dfrac{(4-s)!}{4!}\left[\dfrac{(5-k)!}{(5-k-s)!} - \dfrac{(4-k)!}{(4-k-s)!}\right] & s<4,\ k=1,..,4-s \\ 1-\displaystyle\sum_{i=1}^{4-s} P\{i \mid s\} & s<4,\ k=5-s \\ 1 & s=4,\ k=1 \end{cases} \tag{4}$$

Using this formula the following table for $P\{k \mid s\}$ was computed.

| | | s=1 | s=2 | s=3 | s=4 |
|---|---|---|---|---|---|
| | 1 | 1/4 | 1/2 | 3/4 | 1 |
| k | 2 | 1/4 | 1/3 | 1/4 | N/A |
| | 3 | 1/4 | 1/6 | N/A | N/A |
| | 4 | 1/4 | N/A | N/A | N/A |

$P\{K=k \mid S=s\}$ table

The expected delay given a successful attack with craters is then the following expected value calculation:

$$d(s) = \sum_{i=1}^{5-s} P\{i \mid s\} V_i$$

These values are:

| Number of Companies Attacked s | Delay d(s) |
|---|---|
| 1 | 42 |
| 2 | 45.33 |
| 3 | 47 |
| 4 | 48 |

However, each pass may not be successful in causing a crater on the road. If E denotes the probability of one aircraft getting a crater on a road in one pass, and assuming that different aircraft have independent success probabilities, then the expected delay due to a crater producing attack, here denoted by d*(s), is:

$$d^*(s) = d(s)\left[1-(1-E)^{\text{number of passes in flight}}\right]$$

where d(s) comes from the table above.

## APPENDIX B

### BASIC PROGRAM LISTING

```
10 REM  ****************************************************
20 REM  *                                                  *
30 REM  *              DELAY METHODOLOGY                   *
40 REM  *                                                  *
50 REM  *   N1=# FLIGHTS BY GROUPS OF A/C                  *
60 REM  *   I=FLIGHT NUMBER                                *
70 REM  *   E(I,1)=START TIME=F(I,1)                       *
80 REM  *   E(I,2)=END HEAD DOWN TIME=F(I,2)               *
90 REM  *   E(I,3)=END DAMAGE ASSESSMENT=F(I,3)            *
100 REM *   E(I,4)=END DAMAGE CONTROL=F(I,4)               *
110 REM *   E(I,5)=END IMPAIRED MOVEMENT=F(I,5)            *
120 REM *   E-PURE  F-COMBINED                             *
130 REM *   G(I)=# HOT PASSES PER FLIGHT I                 *
140 REM *   M1=Y/N=1/0 TO: IS UNIT MOVING?                 *
150 REM *   D(I)=Y/N=1/0 TO: DO MUNITIONS CREATE CRATERS?  *
160 REM *   L1=FRACTION OF COMPANY DESTROYED               *
170 REM *   B(I)=EFFECTIVENESS PER A/C ON FLIGHT I         *
180 REM *   R1=REGIMENTAL STRENGTH                         *
190 REM *   T1=RAND DELAY                                  *
200 REM *   C(J)=TABLE OF # COMPANIES ATTACKED, J=# PASSES *
210 REM *   M(K)=EXPECTED DELAY/CRATERS,K=# CO'S ATTACKED  *
220 REM *                                                  *
230 REM ****************************************************
240 REM
250 FIXED 2
260 MAT F=ZER
270 DIM C[37],A$[65],E[20,5],F[20,5],G[20],DI[20],B[20],M[4],Q[20]
280 REM                          **  CRATER DELAY DATA: M(K)
290 DATA 42,45.33,47,48
300 FOR I=1 TO 4
310 READ M[I]
320 NEXT I
330 REM                          **  # CO'S ATTACKED DATA: C(J)
340 DATA 1,2,3,4,4,5,5,6,7,7,7,8,8,8,9,9,9,9,10,10,10,10
350 DATA 10,11,11,11,11,11,11,11,11,11,11,11,11,11,12
360 FOR I=1 TO 37
```

```
370 READ C[I]
380 NEXT I
390 DISP "ENTER DESIGNATION ";
400 INPUT A$
410 DISP "ENTER NUMBER OF FLIGHTS  ";
420 INPUT N1
430 PRINT "FOR EACH FLIGHT I,  ENTER "
440 PRINT "# PASSES , START TIME (MIN FROM 0), CRATERS (0/1),
450 PRINT
460 PRINT                                             EFFECTIVENESS"
470 FOR I=1 TO N1
480 DISP I;
490 INPUT G[I],E[I,1],D[I],B[I]
500 NEXT I
510 DISP "ENTER REGIMENTAL STRENGTH ";
520 INPUT R1
530 DISP "IS UNIT MOVING (1=Y/0=N) ";
540 INPUT M1
550 PRINT "     *** "A$" ***"
560 GOSUB 2590
570 PRINT
580 GOSUB 2610
590 GOSUB 2590
600 REM                        **  COMPUTE AND DISPLAY OLD
610 O1=1                                                RESULTS
620 REM      OPTIONAL PRINTS
630 PRINT
640 PRINT "            NO INTERACTION OF FLIGHTS"
650 PRINT "        5 START TIMES/4 DELAYS AND TOTAL "
660 FOR I=1 TO N1
670 P1=G[I]
680 GOSUB 1690
690 Z0=E[I,1]
700 E[I,2]=Z0+Q1
710 E[I,3]=Z0+Q1+Q2
720 E[I,4]=Z0+Q1+Q2+Q3
730 E[I,5]=Z0+D1
740 REM      OPTIONAL PRINTS
750 PRINT "FLIGHT NUMBER"I
760 PRINT E[I,1],E[I,2],E[I,3],E[I,4],E[I,5]
770 PRINT "  HD             DA              DC   IM   TOTAL"
780 PRINT Q1,Q2,Q3,Q4,D1
790 NEXT I
800 IF N1=1 THEN 1650
810 REM                        **  COMPUTE NEW RESULTS
820 O1=0
830 FOR J=1 TO 5
840 F[1,J]=E[1,J]
850 NEXT J
860 I=1
```

```
870 P1=G[1]
880 GOSUB 1930
890 FOR I=2 TO N1
900 IF E[I,1]>F[I-1,1] THEN 930
910 PRINT " !! ERROR IN INPUT !!  "
920 GOTO 1680
930 IF E[I,1]>F[I-1,2] THEN 950
940 REM                               **  START IN H.D.
950 IF E[I,1]>F[I-1,3] THEN 1100
960 REM                               **  START IN D.A.
970 Z0=F[I-1,2]
980 IF Z0>E[I,2] THEN 1000
990 Z0=E[I,2]
1000 P1=G[I-1]+G[I]
1010 F[I,1]=F[I-1,1]
1020 F[I,2]=Z0
1030 GOSUB 1810
1040 F[I,3]=Z0+Q2
1050 GOSUB 1840
1060 F[I,4]=Z0+Q2+Q3
1070 GOSUB 1930
1080 F[I,5]=Z0+Q2+Q3+Q4
1090 GOTO 1460
1100 IF E[I,1]>F[I-1,4] THEN 1250
1110 REM                              **  START IN D.C.
1120 P1=G[I-1]+G[I]
1130 Z0=0
1140 IF (F[I-1,4]-E[I,1])<(E[I,3]-E[I,2]) THEN 1160
1150 Z0=(F[I-1,4]-E[I,1])-(E[I,3]-E[I,2])
1160 F[I,1]=F[I-1,1]
1170 F[I,2]=E[I,2]
1180 F[I,3]=E[I,3]
1190 F[I,4]=E[I,4]+Z0
1200 GOSUB 1930
1210 D1=(E[I,2]-F[I-1,1])+(E[I,4]-E[I,2])+Q4
1220 D1=D1+Z0
1230 F[I,5]=F[I-1,1]+D1
1240 GOTO 1460
1250 IF E[I,1]>F[I-1,5] THEN 1400
1260 REM                              **  START IN I.M.
1270 D1=(E[I,2]-F[I-1,1])+(E[I,5]-E[I,2])
1280 Z0=0
1290 IF (F[I-1,4]+Q5-E[I,1])<(E[I,3]-E[I,2]) THEN 1310
1300 Z0=(F[I-1,4]+Q5-E[I,1])-(E[I,3]-E[I,2])
1310 D1=D1+Z0
1320 F[I,1]=F[I-1,1]
1330 F[I,2]=E[I,2]
1340 F[I,3]=E[I,3]
1350 F[I,4]=E[I,4]
```

```
1360 P1=G[I]
1370 GOSUB 1930
1380 F[I,5]=E[I,4]+Q4+Z0
1390 GOTO 1460
1400 REM                              **  DISJOINT TIME INTERVALS
1410 FOR J=1 TO 4
1420 F[I,J]=E[I,J]
1430 NEXT J
1440 GOSUB 1930
1450 F[I,5]=F[I,4]+Q4
1460 NEXT I
1470 REM                              **  DISPLAY NEW  RESULTS
1480 GOSUB 2590
1490 PRINT
1500 PRINT "                   FLIGHTS INTEGRATED"
1510 PRINT "               5 START TIMES/4 DELAYS AND ACCUMULATED
1520 FOR I=1 TO N1                                         TOTAL DELAY"
1530 IF I>1 THEN 1560
1540 D0=E[1,5]-E[1,1]
1550 GOTO 1600
1560 IF F[I,1]>F[I-1,5] THEN 1590
1570 D0=D0+(F[I,5]-F[I-1,5])
1580 GOTO 1600
1590 D0=D0+(F[I,5]-F[I,1])
1600 PRINT "RESULTANT OF FLIGHT"I
1610 PRINT F[I,1],F[I,2],F[I,3],F[I,4],F[I,5]
1620 PRINT "  HD             DA             DC   IM  TOTAL"
1630 PRINT F[I,2]-F[I,1],F[I,3]-F[I,2],F[I,4]-F[I,3],F[I,5]
1640 NEXT I                                             -F[I,4],D0
1650 GOSUB 2590
1660 PRINT
1670 PRINT
1680 END
1690 REM                              **  DELAY COMPUTATIONS
1700 GOSUB 1760
1710 GOSUB 1810
1720 GOSUB 1840
1730 GOSUB 1930
1740 D1=Q1+Q2+Q3+Q4
1750 RETURN
1760 REM                              **  HEADS DOWN = Q1  **
1770 Q1=P1*C[P1]/12
1780 IF M1=0 THEN 1800
1790 Q1=P1
1800 RETURN
1810 REM                              **  DAMAGE ASSESSMENT = Q2  **
1820 Q2=27*C[P1]/12
1830 RETURN
1840 REM                              **  DAMAGE CONTROL = Q3  **
1850 L1=(P1*B[I]/C[P1])/(R1/12)
1860 IF L1<0.999 THEN 1880
```

```
1870 PRINT " !! ALL  DESTROYED  !!  "
1880 T1=720*L1/(1-L1)
1890 IF T1>10 THEN 1910
1900 T1=10
1910 Q3=T1*C[P1]/12
1920 RETURN
1930 REM                              **  IMPAIRED MOVEMENT = Q4  **
1940 Q4=0
1950 IF M1=0 THEN 2580
1960 IF O1=0 THEN 2040
1970 Q4=Q5=14*(1-(1-B[I])↑P1)
1980 IF D[I]=0 THEN 2580
1990 A8=C[P1]
2000 IF A8<4 THEN 2020
2010 A8=4
2020 Q4=Q5+M[A8]*(1-(1-B[I])↑P1)
2030 GOTO 2580
2040 REM    CASE OF O1=0;  I=1
2050 IF I>1 THEN 2170
2060 Q5=Q[I]=14*(1-(1-B[I])↑P1)
2070 Q4=Q5
2080 IF D[1]=0 THEN 2580
2090 A8=C[P1]
2100 IF A8<4 THEN 2120
2110 A8=4
2120 Q6=M[A8]*(1-(1-B[I])↑P1)
2130 Q4=Q5+Q6
2140 Q7=F[1,4]+Q5
2150 J0=1
2160 GOTO 2580
2170 REM     I>1
2180 IF P1=G[I] THEN 2210
2190 Q5=Q[I]=14*(1-(1-(B[I]*G[I]+B[I-1]*G[I-1])/P1)↑P1)
2200 GOTO 2220
2210 Q5=Q[I]=14*(1-(1-B[I])↑G[I])
2220 REM:  D(I)=1,O1=0,M1=1,I>1
2230 REM:  Q6=CRATER DELAY
2240 REM:  P1=TOTAL HOT PASSES
2250 REM:  Q7=TIME AT OLD CRATER DELAY
2260 IF D[I]=1 THEN 2420
2270 IF Q7>0 THEN 2300
2280 Q4=Q5
2290 GOTO 2580
2300 REM  NO NEW CRATERS, BUT CRATERS HAVE BEEN EMPLOYED
2310 GOSUB 2700
2320 B9=D9
2330 B8=(F[I,4]+Q5)-Q7
2340 B7=B8-B9
2350 IF B7>0 THEN 2370
2360 B7=0
2370 Q8=0
```

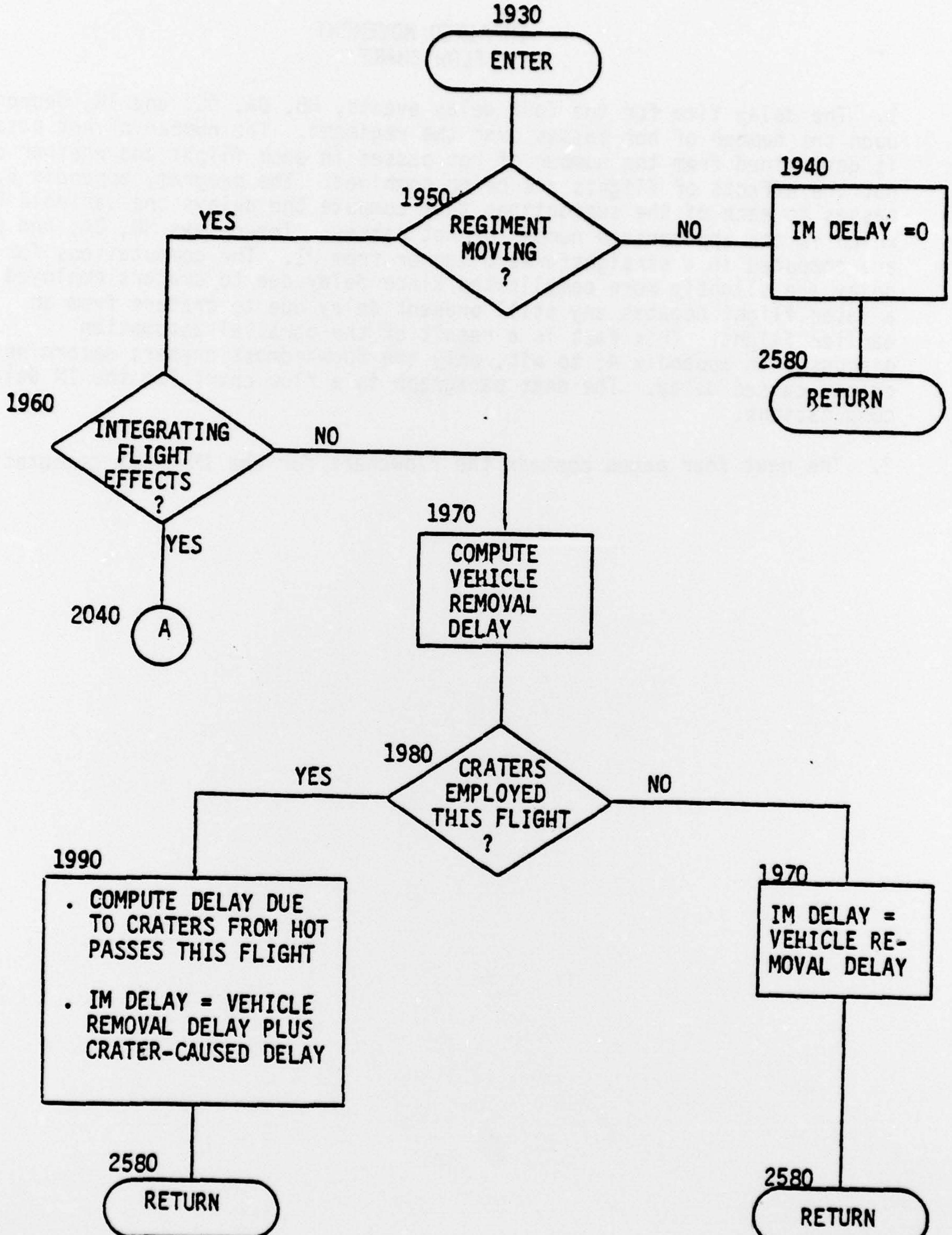
```
2380 IF B7>Q6 THEN 2400
2390 Q8=Q6-B7
2400 Q4=Q5+Q8
2410 GOTO 2580
2420 REM NEW CRATERS
2430 A9=G[I]
2440 A8=C[A9]
2450 IF A8<4 THEN 2470
2460 A8=4
2470 IF P1=G[I] THEN 2540
2480 IF D[I-1]=0 THEN 2540
2490 A8=C[P1]
2500 IF A8<4 THEN 2520
2510 A8=4
2520 Q6=M[A8]*(1-(1-(B[I]*G[I]+B[I-1]*G[I-1])/P1)↑P1)
2530 GOTO 2550
2540 Q6=M[A8]*(1-(1-B[I])↑G[I])
2550 Q4=Q5+Q6
2560 Q7=F[I,4]+Q5
2570 J0=I
2580 RETURN
2590 PRINT "-----------------------------------------
2600 RETURN
2610 REM                        **  INPUTS
2620 PRINT "NUMBER OF FLIGHTS                 "N1
2630 PRINT "REGIMENTAL STRENGTH               "R1
2640 PRINT "MOVING ? (1=YES,0=NO)             "M1
2650 PRINT "FLIGHT # # PASSES START TIME  CRATER(1/0)
2660 FOR I=1 TO N1                              EFFECTIVE"
2670 PRINT I,G[I],E[I,1],D[I],B[I]
2680 NEXT I
2690 RETURN
2700 REM                        **  RUNNING TOTAL(NON-CRATER)
2710 D9=0                                      DELAY SUBROUTINE
2720 FOR J=J0+1 TO I
2730 IF F[J,1]>(F[J-1,4]+Q[J-1]) THEN 2760
2740 D9=D9+(F[J,4]+Q[J])-(F[J-1,4]+Q[J-1])
2750 GOTO 2770
2760 D9=D9+(F[J,4]+Q[J])-(F[J,1])
2770 NEXT J
2780 RETURN
```

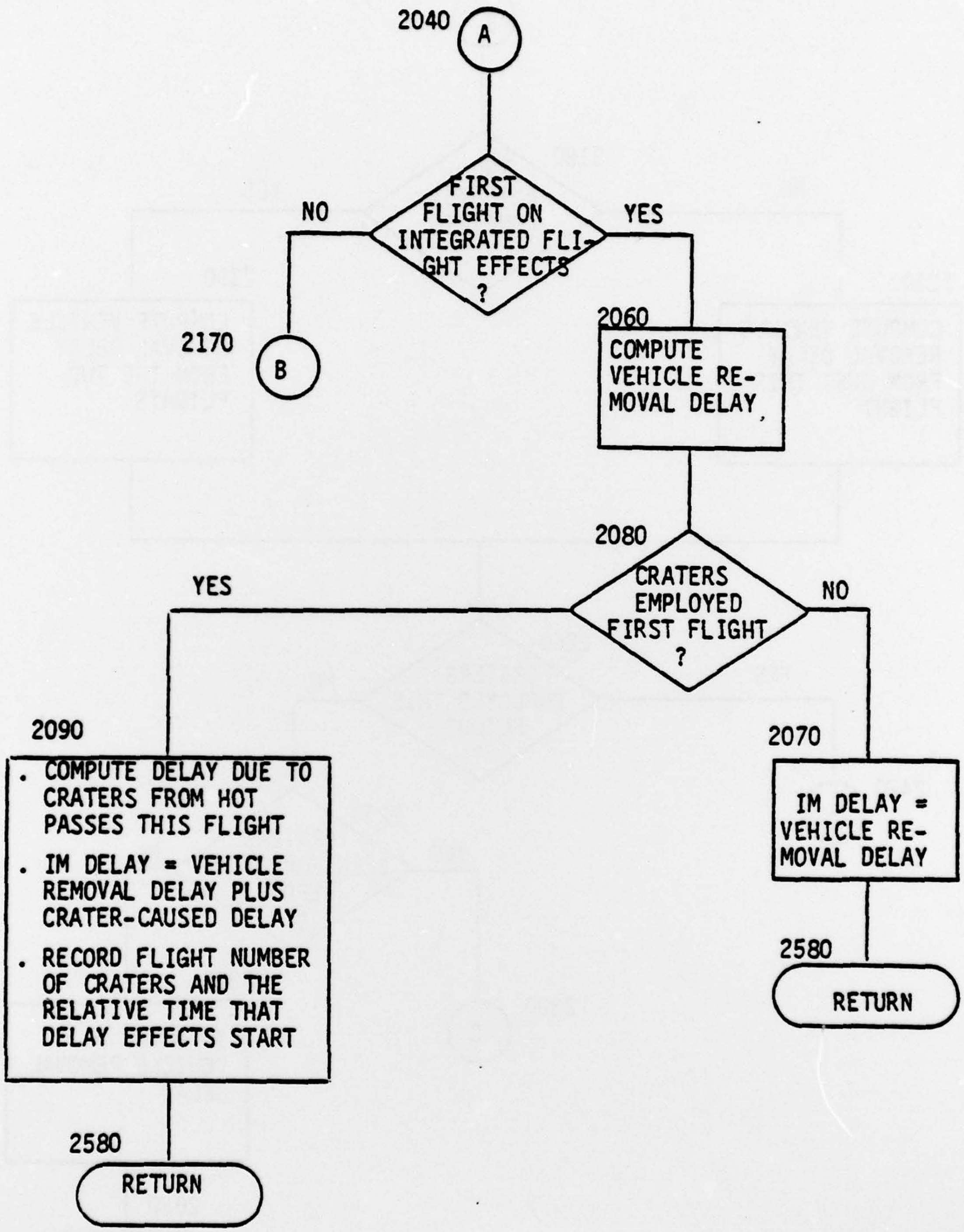
APPENDIX C

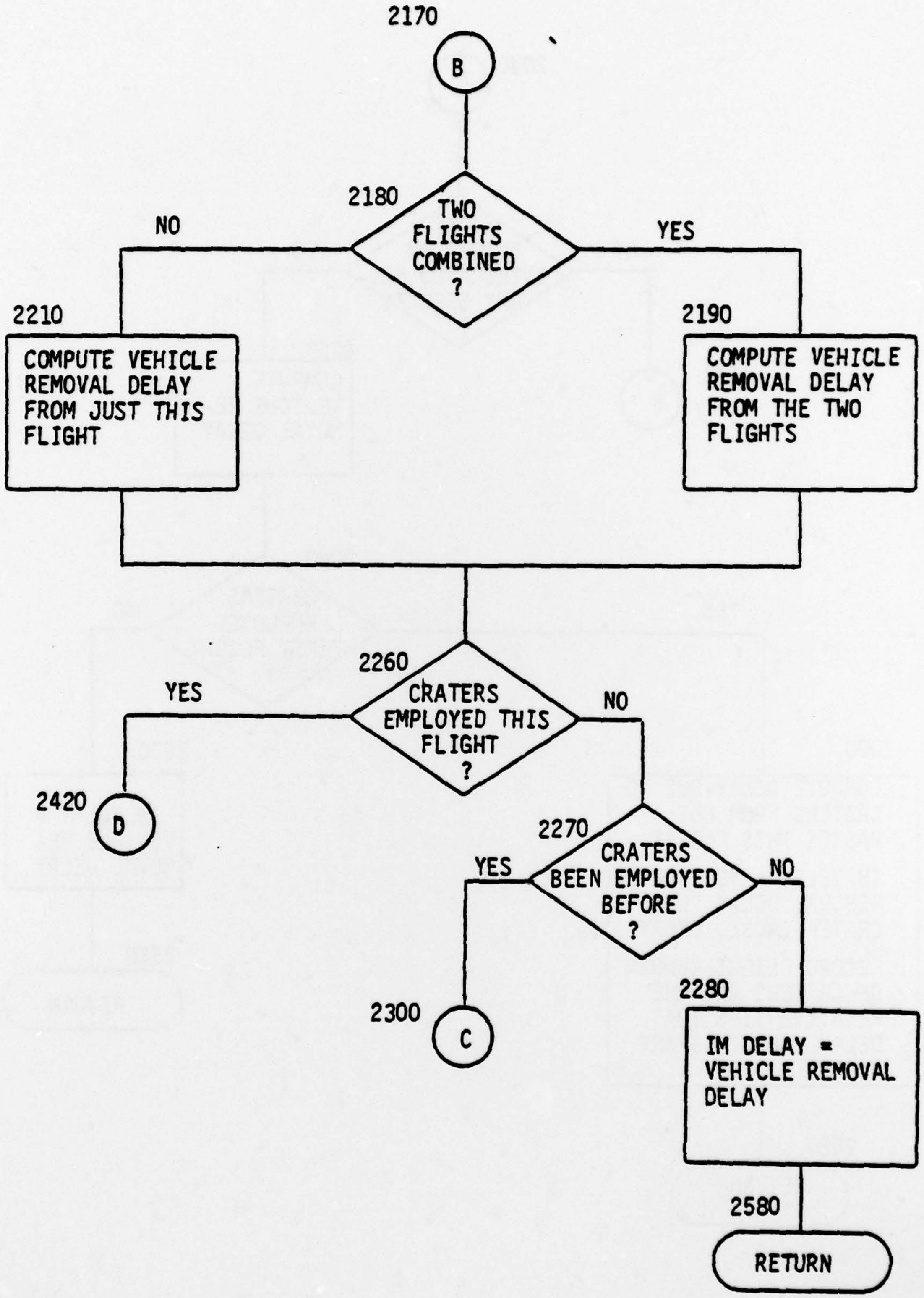
IMPAIRED MOVEMENT
FLOW CHART

1. The delay time for the four delay events, HD, DA, DC, and IM, depends upon the number of hot passes over the regiment. The number of hot passes is determined from the number of hot passes in each flight and whether or not the effects of flights are being combined. The program, appendix B, passes to each of the subroutines that compute the delays the variable P1, which is the appropriate number of hot passes. The delays HD, DA, and DC are computed in a straightforward manner from P1. The computations for IM delay are slightly more complicated since delay due to craters employed in a later flight negates any still present delay due to craters from an earlier flight. This fact is a result of the parallel assumption discussed in appendix A; to wit, only the forwardmost craters determine crater-caused delay. The next paragraph is a flow chart for the IM delay computations.

2. The next four pages contain the flowchart for the IM delay computations.


1930
ENTER
1950
REGIMENT MOVING ?
YES
NO
1940
IM DELAY =0
2580
RETURN
1960
INTEGRATING FLIGHT EFFECTS ?
NO
YES
2040
A
1970
COMPUTE VEHICLE REMOVAL DELAY
1980
CRATERS EMPLOYED THIS FLIGHT ?
YES
NO
1990
• COMPUTE DELAY DUE TO CRATERS FROM HOT PASSES THIS FLIGHT
• IM DELAY = VEHICLE REMOVAL DELAY PLUS CRATER-CAUSED DELAY
1970
IM DELAY = VEHICLE RE-MOVAL DELAY
2580
RETURN
2580
RETURN

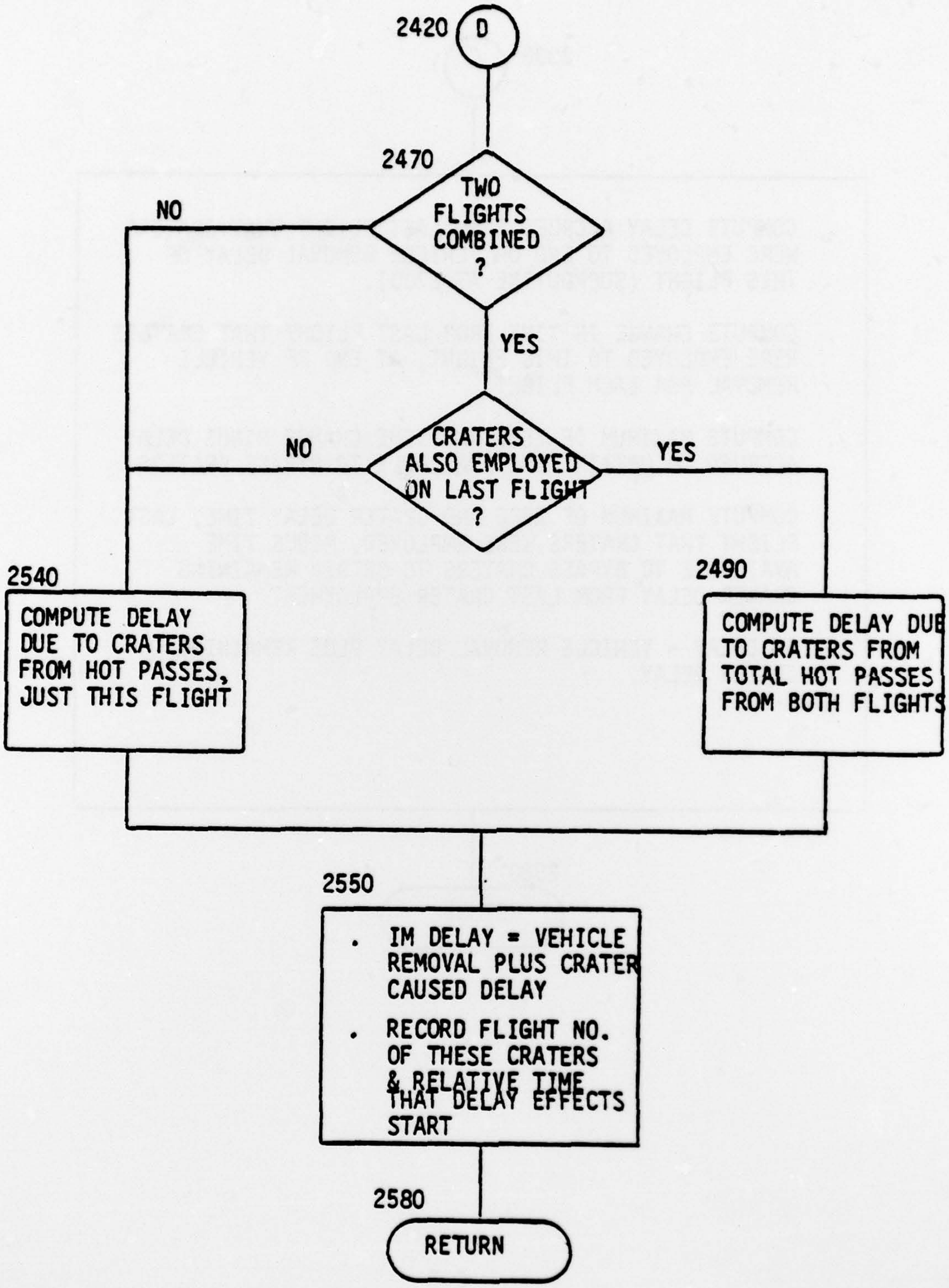

2040
A
FIRST FLIGHT ON INTEGRATED FLIGHT EFFECTS ?
NO
YES
2170
B
2060
COMPUTE VEHICLE REMOVAL DELAY
2080
CRATERS EMPLOYED FIRST FLIGHT ?
YES
NO
2090
. COMPUTE DELAY DUE TO CRATERS FROM HOT PASSES THIS FLIGHT
. IM DELAY = VEHICLE REMOVAL DELAY PLUS CRATER-CAUSED DELAY
. RECORD FLIGHT NUMBER OF CRATERS AND THE RELATIVE TIME THAT DELAY EFFECTS START
2070
IM DELAY = VEHICLE REMOVAL DELAY
2580
RETURN
2580
RETURN


2170
B
2180
TWO FLIGHTS COMBINED ?
NO
YES
2210
COMPUTE VEHICLE REMOVAL DELAY FROM JUST THIS FLIGHT
2190
COMPUTE VEHICLE REMOVAL DELAY FROM THE TWO FLIGHTS
2260
CRATERS EMPLOYED THIS FLIGHT ?
YES
NO
2420
D
2270
CRATERS BEEN EMPLOYED BEFORE ?
YES
NO
2300
C
2280
IM DELAY = VEHICLE REMOVAL DELAY
2580
RETURN

2300 C

- COMPUTE DELAY ACCRUED FROM LAST FLIGHT THAT CRATERS WERE EMPLOYED TO END OF VEHICLE REMOVAL DELAY OF THIS FLIGHT (SUBROUTINE AT 2700).
- COMPUTE CHANGE IN TIME FROM LAST FLIGHT THAT CRATERS WERE EMPLOYED TO THIS FLIGHT, AT END OF VEHICLE REMOVAL FOR EACH FLIGHT
- COMPUTE MAXIMUM OF ZERO AND TIME CHANGE MINUS DELAY ACCRUED TO OBTAIN TIME AVAILABLE TO BYPASS CRATERS
- COMPUTE MAXIMUM OF ZERO AND CRATER DELAY TIME, LAST FLIGHT THAT CRATERS WERE EMPLOYED, MINUS TIME AVAILABLE TO BYPASS CRATERS TO OBTAIN REMAINING CRATER DELAY FROM LAST CRATER EMPLOYMENT
- IM DELAY = VEHICLE REMOVAL DELAY PLUS REMAINING CRATER DELAY.

2580 RETURN


2420
D
2470
TWO FLIGHTS COMBINED ?
NO
YES
CRATERS ALSO EMPLOYED ON LAST FLIGHT ?
NO
YES
2540
COMPUTE DELAY DUE TO CRATERS FROM HOT PASSES, JUST THIS FLIGHT
2490
COMPUTE DELAY DUE TO CRATERS FROM TOTAL HOT PASSES FROM BOTH FLIGHTS
2550
. IM DELAY = VEHICLE REMOVAL PLUS CRATER CAUSED DELAY
. RECORD FLIGHT NO. OF THESE CRATERS & RELATIVE TIME THAT DELAY EFFECTS START
2580
RETURN

## APPENDIX D

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# REPORT DOCUMENTATION PAGE

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number):

This technical paper presents modifications to the methodology concerning delay imposed on ground forces due to interdiction air strikes as presented in CACDA TP 3-79. That paper presented the rationale underlying the development of a new delay methodology for TALON. The methodology involves four types of mutually exclusive, exhaustive delay events that were imposed upon regiments due to air strikes. This paper briefly reviews the computations for three of those delays and presents a new technique for computing delay caused by crater-producing munitions. This paper also details the resultant

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20. Abstract (continued)

delay from the interaction of consecutive but separate flights of two to four aircraft. The total regimental delay is the sum of the four types of delay in the case of an air strike against an undelayed regiment. However, if the regiment is currently in a delay status from a previous air strike, then the resultant total delay for the regiment depends on the type of delay being imposed at the time of the subsequent strike. Example delays are given for attacks of one, two, and four aircraft. The methodology is equally applicable for Blue delay due to Red air strikes as well as Red delay due to Blue air strikes.